HOW CAN IMPROVEMENTS BE MADE TO THE UNITED STATES METRORAIL SYSTEM (WITH A FOCUS ON THE WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY METRORAIL SYSTEM) TO ENHANCE SAFETY FOR ITS RIDERS?

A thesis presented to the Faculty of the U.S. Army
Command and General Staff College in partial
fulfillment of the requirements for the
degree

MASTER OF MILITARY ART AND SCIENCE
Homeland Security Studies

by

KEVIN R. WALLEN, MAJOR, U.S. ARMY
B.S., Eastern Kentucky University, Richmond, Kentucky, 2002

Fort Leavenworth, Kansas
2016

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)* 10-06-2016	**2. REPORT TYPE** Master's Thesis	**3. DATES COVERED** *(From - To)* AUG 2015 – JUNE 2016
4. TITLE AND SUBTITLE How can Improvements be made to the United States Metrorail System (with a Focus on the Washington Metropolitan Area Transit Authority Metrorail System) to Enhance Safety for its Riders?		**5a. CONTRACT NUMBER**
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Kevin R. Wallen, Major		**5d. PROJECT NUMBER**
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Command and General Staff College ATTN: ATZL-SWD-GD Fort Leavenworth, KS 66027-2301		**8. PERFORMING ORG REPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)		**10. SPONSOR/MONITOR'S ACRONYM(S)**
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release; Distribution is Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

An estimated 4,000,000,000 of Americans use Metrorail mass transit on an annual basis, with 271,160,000 of those riders using the Washington Metropolitan Area Transit Authority (WMATA) Metrorail system. With frequent accidents and crimes happening on these systems, the need for rider safety has dramatically increased. The research question investigates Metrorail accidents that resulted in injuries of its riders, loss of equipment, and the costs associated. These accidents are results of equipment malfunctions, operator error, and command and control functions within the administration. The need for rider safety is a security concern for all riders involved, whether it is citizens commuting to work, families traveling into the National Capital Region, or tourists that are traveling to visit the Nations Capital. The public opinion of the WMATA Metrorail system has been on a gradual decline over the years due to the accidents, current system malfunctions, and rising commuter costs.

15. SUBJECT TERMS
Homeland Security, Metrorail, Safety

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. PHONE NUMBER** *(include area code)*
(U)	(U)	(U)	(U)	81	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

MASTER OF MILITARY ART AND SCIENCE

THESIS APPROVAL PAGE

Name of Candidate: Major Kevin R. Wallen

Thesis Title: How can Improvements be made to the United States Metrorail System (with a Focus on the Washington Metropolitan Area Transit Authority Metrorail System) to Enhance Safety for its Riders?

Approved by:

____, Thesis Committee Chair
O. Shawn Cupp, Ph.D.

____, Member
LTC Seth A. Weaver, M.A.

____, Member
LTC Donald E. Bishop, M.S.

Accepted this 10th day of June 2016 by:

____, Director, Graduate Degree Programs
Robert F. Baumann, Ph.D.

ABSTRACT

HOW CAN IMPROVEMENTS BE MADE TO THE UNITED STATES METRORAIL SYSTEM (WITH A FOCUS ON THE WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY METRORAIL SYSTEM) TO ENHANCE SAFETY FOR ITS RIDERS? by Major Kevin R. Wallen, 81 pages.

An estimated 4,000,000,000 of Americans use Metrorail mass transit on an annual basis, with 271,160,000 of those riders using the Washington Metropolitan Area Transit Authority (WMATA) Metrorail system. With frequent accidents and crimes happening on these systems, the need for rider safety has dramatically increased. The research question investigates Metrorail accidents that resulted in injuries of its riders, loss of equipment, and the costs associated. These accidents are results of equipment malfunctions, operator error, and command and control functions within the administration. The need for rider safety is a security concern for all riders involved, whether it is citizens commuting to work, families traveling into the National Capital Region, or tourists that are traveling to visit the Nations Capital. The public opinion of the WMATA Metrorail system has been on a gradual decline over the years due to the accidents, current system malfunctions, and rising commuter costs.

ACKNOWLEDGMENTS

I would first like to thank my beautiful wife, Jamon. Thank you for your constant support and encouragement while I completed this Thesis. To my son, Damon and daughter, Katherine-thank you for everything, my greatest gift is being your Dad. Thank you to my family and friends, I appreciate all of your support.

I would specifically like to thank my committee-Dr. O. Shawn Cupp, LTC Seth Weaver, and LTC Donald Bishop. Their guidance and professionalism is why I chose them as committee members. Thank you for your wisdom and input throughout this process.

A special thank you goes to my editor, Mrs. Karen Wallsmith. Thank you for your professionalism and input as I completed this task.

Thank you to all the Soldiers and their families that I have had the pleasure to serve with over my career.

TABLE OF CONTENTS

ACRONYMS

ATC	Automatic Train Control
NTSB	National Transportation Safety Board
OCC	Operations Control Center
WMATA	Washington Metropolitan Area Transit Authority

ILLUSTRATIONS

TABLES

CHAPTER 1

INTRODUCTION

Mass Transit Security in the United States

Public Transportation

Public transportation in the United States is a crucial part of the solution to the nation's economic, energy, and environmental challenges-helping to bring a better quality of life. In increasing numbers, people are using public transportation and local communities are expanding public transit services. Every segment of American society-individuals, families, communities, and businesses-benefits from public transportation.[1]

Public Transportation Consists of a Variety of Modes to include: Buses, Trolleys and Light Rail, Subways, Commuter Trains, Streetcars, Cable Cars, Van Pool Services, Paratransit services for Senior Citizens and people with disabilities, Ferries and Water Taxis, Monorails, and Tramways. These modes of transportation are used on a daily basis by United States Citizens to include travel to work, school, vacation, or other activities.

In 2014, Americans took 10.8 billion trips on public transportation, the highest in 58 years. Since 1995, public transportation ridership is up 39 percent, outpacing population growth, which is up 21 percent, and vehicle miles traveled, which is up 25 percent. People board public transportation 36 million times each weekday. Public transportation is a $61 billion dollar industry that employs more than 400,000 people.[2]

[1] American Public Transportation System, "Public Transportation Benefits," accessed 17 November 2015, http://www.apta.com/mediacenter/ptbenefits/Pages/default.aspx.

[2] Ibid.

Metrorail Transportation

In Fiscal Year 2014, 12,831,495 people in the United States of America used Metrorail transit on a daily basis. In Fiscal Year 2014, an estimated 4,000,000,000 people in the United States use Metrorail transit throughout the year. Mass transit is used for commuting to work, school, and personal interests.[3]

Washington Metropolitan Area Transit Authority

The Washington Metropolitan Area Transit Authority (WMATA) Metrorail system began serving the Washington, D.C. metropolitan area in 1976.

In Fiscal Year 2015, WMATA averaged 790,790 riders per weekday. During that same year, WMATA served 206,396,040 riders.[4]

Thesis Question

The thesis question concerns the current safety of the mass transit security in the United States with a focus on the safety of the WMATA Metrorail System. This question centers on the history of the WMATA Metrorail System, past accidents that have happened on the rail system, and recommended improvements to improve the safety of the Metrorail system. These three influences show a holistic view of the system. They are interrelated and directly impact the physical safety of the system to include rider safety. The primary question is: How can mass transit security in the United States (with a focus on the WMATA) be improved to protect its riders?

---

[3] Ibid.

[4] Washington Metropolitan Area Transit Authority, "Metro Facts," accessed 11 May 2016, http://www.wmata.com/about_metro/docs/Metro%20Facts%202016.pdf.

The following are subordinate questions to this thesis: What is the history of the WMATA Metrorail System? What accidents have occurred in the past that has resulted in the loss of life or equipment? What recommendations and improvements can be made to improve rider security?

Significance of Study

This research is significant in relation to the safety of Metrorail systems across the United States. These recommendations for the WMATA Metrorail System will include equipment improvements, enhanced operator training, and enforcement of policies and procedures to enhance overall rider safety.

Assumptions

Metrorail security and safety will always be a factor when using mass transit. One assumption is that with the large amount of use of mass transit systems, will be that of system safety. Many rail systems use off-peak or non-business hours to conduct system maintenance, repairs, and improvements. Another assumption is that as more riders use these systems, necessary operator training and operations center procedures will improve to help make Metrorails safer and more efficient. With all of this, comes a financial impact on the Metrorail systems; more operators are needed to transport more riders and additional hours of track closures will happens as track improvements are made.

Limitations

There is a large number of research material on the topic of mass transit security around the world. However, for this thesis, the research has a small look at the overall

mass transit system in the United States, but with a focus on the WMATA Metrorail System that services the Washington, D.C. Metropolitan Area.

This thesis will focus on the WMATA that began operations in 1976 and will detail the operations, safety, and security of that Metrorail System.

The research will cover case studies and federal investigations of incidents on the WMATA to include collisions, track worker accidents, and derailments. These incidents will be summarized, to detail the importance of the event, but will be limited as to not allow the thesis to grow uncontrollably.

Conclusion

This study will focus on the history of the Metrorail Systems, provide case study analysis of past accidents involving the WMATA Metrorail, and discuss future and recommend improvements to that system. The understanding of "Metrorail Security" is a topic that is not only a concern in the United States, but across the globe. As there have been terrorist attacks involving Metrorail Stations, rider safety remains a worldwide concern.

CHAPTER 2

LITERATURE REVIEW

Introduction

The review of literature for this thesis can be divided into three areas. These areas are current statistics and historical data trends of mass rail transit, past WMATA accident case studies to include the National Transportation Safety Board (NTSB) Investigative Process, and proposed future safety improvements across the WMATA Metrorail System. The areas will be discussed in relation to mass transit use and security measures since 1976, which is the year that the WMATA began servicing the National Capital Region. There is a significant amount of research on the topic area within the specified time frame. This literature will be discussed based upon the topics that impact the thesis.

Understanding of the United States Metrorail System

What is a Metro? As defined by the International Association of Public Transit, a metro is an urban guided transport system, mostly on rails, running on an exclusive right-of-way without any interference from other traffic or level crossings and mostly with some degree of drive automation and train protection. These design features allow high capacity trains to run with short headways and high commercial speed. Metros are therefore suitable for the carriage of high passenger flows.[5]

---

[5] International Association of Public Transport, "Statistics Brief–World Metro Figures," accessed 15 February 2016, http://www.uitp.org/sites/default/files/cck-focus-papers-files/Metro%20report%20Stat%20brief-web_oct2014.pdf.

This thesis has a primary focus on the Washington Metropolitan Area Transit System. However, this research studied the largest (New York City) and the smallest (Greater Cleveland Regional Transit Authority) of the 14 United States Metrorail Systems. These comparisons provide a better understanding of Metrorail Systems in the United States.

New York City Transit

This system is the largest of the 14 United States Metrorail Systems, based on annual ridership in 2014. This system opened in 1904 and launched an unprecedented era of growth and prosperity for New York City. The New York City Transit System operates 24 hours a day, seven days a week. Serves the boroughs of Manhattan, Brooklyn, Queens, and the Bronx. In 2015, The New York City Transit System had a $10.6 billion dollar operating budget. The annual ridership was over 2.4 billion passengers, with an average weekday ridership of over 7.6 million passengers. The system has a total of 24 subway lines, 659 track miles, and 468 subway stations.[6]

Greater Cleveland Regional Transit Authority

This system is the smallest of the 14 United States Metrorail Systems, based on annual ridership in 2014. The Greater Cleveland Regional Transit Authority provides transportation services for approximately 50 million riders per years and approximately 200,000 customers on a typical weekday. The system began light-rail operations in 1913.

[6] The Metropolitan Transit Authority, “Network,” accessed 20 May 2016, http://web.mta.info/mta/network.htm#statsnyct.

Currently, there are 52 stations, 69 miles of track, and an estimated operating budget of $300 million dollars.[7]

Understanding of the WMATA Metrorail System

The following data details current statistical information on WMATA:

This study focuses on the Washington Metropolitan Area Transportation Authority (WMATA). Current statistical data for WMATA is as follows:

Average daily riders: 829,200

Number of stations: 91-current expansion will add 6 additional lines on the Silver Line that is scheduled to be completed by 2018

Number of lines: 6

FY [Fiscal Year] 2015 Operating Budget: $1.76 billion dollars[8]

The system is the second busiest in the United States, serving stations in Virginia, Maryland, and the District of Columbia.

The WMATA Metrorail system has six-color coded rail lines: Red, Orange, Silver, Blue, Yellow, and Green. The layout of the system makes it possible to travel between any two stations with no more than a single transfer.

System service begins at 5 a.m. on weekdays and 7 a.m. on weekends and closes at 12 a.m. Sunday through Thursday and 3 a.m. Friday and Saturday, eastern standard time. Hours may be adjusted due to special events in the area to include Washington Redskins football, Washington National baseball, and other events held in the Washington, D.C area that expect large attendance figures.[9] Other events that affect the hours are Independence Day Celebrations, National Mall Events, and Presidential Inaugurations.

---

[7] Greater Cleveland Regional Transit Authority, "RTA Overview," accessed 20 May 2016, http://www.riderta.com/overview.

[8] Washington Metropolitan Area Transit Authority, "FY 2015 Approved Budget," accessed 20 May 2016, https://www.wmata.com/about_metro/docs/FY2015 %20Approved%20Budget%20Book.pdf.

[9] Washington Metropolitan Area Transit Authority, "Metrorail," accessed 17 November 2015, http://www.wmata.com/rail/.

Figure 1. The WMATA Metrorail System Layout as of 16 February 2016

Source: Washington Metropolitan Area Transit Authority, "Metro System Map," accessed 17 November 2015, http://www.wmata.com/rail/docs/color_map_silverline.pdf.

Past WMATA Accident Case Studies

This research covers three case studies that involve equipment damage, injuries, and fatalities. The accidents studied were results of failures of management to understand operating systems, operator error, and equipment failure. The accidents studies resulted in investigations by the NTSB, which provided analysis of the accidents and recommendations to the WMATA for future system improvements.

The first case study took place on 6 January 1996, and involved the collision of WMATA Train T-111 with a standing train at the Shady Grove Metro Station, located in Gaithersburg, Maryland. The accident resulted in the Operator of Train T-111 being fatally wounded and the total property damages were between $2.1 and $2.6 million dollars.

The second case study took place on 3 November 2004, and involved the collision between two WMATA Trains at the Woodley Park Metro Station in Washington, DC. The accident resulted in 20 passengers being transported to local hospitals and estimated property damage of $3.5 million dollars.

The third case study took place on 22 June 2009, and involved the collision of two WMATA Trains near the Fort Totten Metro Station in Washington, DC. The accident resulted in nine people including the train operator were killed. Emergency response agencies reported transporting 52 people to local hospitals. Damage to train equipment was estimated to be $12 million dollars.

National Transportation Safety Board Investigations

The NTSB was established in 1967 to conduct independent investigations of all civil aviation accidents in the United States and major accidents in the other modes of

transportation. It is not part of the Department of Transportation, nor organizationally affiliated with any of U.S. Department of Transportation's modal agencies, including the Federal Aviation Administration. The Safety Board has no regulatory or enforcement powers.

To ensure that Safety Board investigations focus only on improving transportation safety, the Board's analysis of factual information and its determination of probable cause cannot be entered as evidence in a court of law.

Each NTSB Investigation has a "Go Team." The purpose of each Go Team is to begin the investigations of major accidents at the accident scene as quickly as possible. The team is located at NTSB Headquarters in Washington, DC and members are assigned on a rotational basis to respond to the scene of major accidents. The teams have been investigating catastrophic accidents for 35 years. While on duty rotation, team members must be reachable 24 hours a day.

Safety recommendations are the most important part of the Safety Board's mandate. Safety deficiencies must be addressed immediately, and often issues recommendations before the completion of investigations. Recommendations are based on findings of the investigation, and may address deficiencies that do not pertain directly to what is ultimately determined to be the cause of the accident.

The majority of accident investigations require more months of tests and analysis, which eventually leads to the preparation of a draft final report by the Safety Board Staff. Once the investigations are final, they are then made available to the public. The

investigative reports contain the Safety Board's conclusions, probable cause and safety recommendations.[10]

Future WMATA Metrorail Safety and Security Improvements

The WMATA Metrorail Safety and Security Improvements as of 31 March 2016, include: installing new Metro and public safety radio systems, including cabling for cell phone service in tunnels; activating tunnel segments for telecom providers to offer cell service; establish online tracking of 732 actions being taken to meet all Federal Transit Administration safety recommendations; establish online tracking of actions being taken to meet all NTSB recommendations; increase the number of Metro Transit Police Officers on rail and bus system, increasing the visibility of law enforcement personnel in stations and on buses with enhanced uniforms; and strengthen command center operations to improve emergency planning and service recovery.[11]

Conclusion

The literature concerning this research of the WMATA Metrorail System covers the beginning of system service in 1976 to current safety and security improvement recommendations, dated 31 March 2016. Case studies on the WMATA Metrorail System covers three separate incidents and are spaced out in time, covering events in 1996, 2004, and 2009.

[10] National Transportation Safety Board, "Investigations," accessed 19 May 2016, http://www.ntsb.gov/investigations/process/Pages/default.aspx.

[11] Washington Metropolitan Area Transit Authority, "Customer Accountability Report," 31 March 2016, accessed 27 April 2016, https://www.wmata.com/about_metro/general_manager/performance/CARe.pdf.

CHAPTER 3

RESEARCH METHODOLOGY

Three Areas of Review

The research method used in this thesis is a qualitative methodology using a research design of case study. This allows for a comprehensive and historical interpretation of the facts concerning the thesis. The information for this methodology already exists so no generation or outside collection of external data is required. One disadvantage inherent to this method is the requirement to clearly state what information is used and searched during the discovery phase of this thesis. Another disadvantage to this method is that the research is restricted to the data that already exists.

This thesis is research into the current Metrorail Systems in the United States, as it focuses on improving system operations and improving rider safety. This research takes into account the 14 Metrorail Systems operating across the United States, but has a focus on the Washington, DC Metrorail System, which is otherwise known as the WMATA. The primary question is, How can mass transit security in the United States (with a focus on the WMATA) be improved to protect its riders? The following are subordinate questions to this thesis: What is the history of the WMATA Metrorail System? What accidents have occurred in the past that has resulted in the loss of life or equipment? What recommendations and improvements can be made to improve rider security?

First Area of Review (Current and Historical Data Trends of Mass Rail Transit-Worldwide to DC Metro)

Metros are the backbone of public transportation systems in cities of different sizes around the world. As of October 2014, 148 cities have a metro system and there are

close to 540 lines in total. Together, those systems carry over 150 million passengers per day.[12]

Two-thirds of the world's metro systems are located in Asia and Europe (50 and 45 respectively). There are currently 14 metro systems located in the United States of America. Those locations and systems are as follows with annual ridership for 2014:

Table 1. The 14 United States Metrorail Systems (as of 2014)

System	Transit Agency	City/Area Served	2014 Ridership	Average Weekday Ridership	System Length	Year Opened	Number of Stations	Number of Lines
New York City Subway	New York City Transit Authority	New York City, NY	2,758,485,000	9,060,800	233 miles	1904	469	24
Washington Metro	Washington Metropolitan Area Transit Authority	Washington, D.C.	271,160,000	829,200	117 miles	1976	91	6
Chicago 'L'	Chicago Transit Authority	Chicago, IL	239,100,200	753,600	102.8 miles	1892	145	8
MBTA Subway ("The T")	Massachusetts Bay Transportation Authority	Boston, MA	174,820,200	560,500	38 miles	1901	53	4
Bay Area Rapid Transit (BART)	Bay Area Rapid Transit District	San Francisco Bay Area, CA	132,314,200	447,200	104 miles	1972	44	5
SEPTA	Southeastern Pennsylvania Transportation Authority	Philadelphia, PA	96,709,400	342,600	36.7 miles	1907	75	3
Port Authority Trans-Hudson (PATH)	Port Authority of New York and New Jersey	Manhattan, NY; Jersey City and Newark, NJ	73,649,000	250,700	13.8 miles	1908	13	4

[12] UITP Advanced Public Transport, "October 2014 Statistics Brief," accessed 15 February 2016, http://www.uitp.org/sites/default/files/cck-focus-papers-files/Metro%20 report%20Stat%20brief-web_oct2014.pdf.

MARTA Rail System	Metropolitan Atlanta Rapid Transit Authority	Atlanta, GA	71,504,600	232,100	47.6 miles	1979	38	4
Metro Rail	Los Angeles County Metropolitan Transportation Authority	Los Angeles, CA	48,724, 700	153,000	17.4 miles	1993	16	2
Metrorail	Miami-Dade Transit	Miami, FL	21,722,100	74,600	24.4 miles	1984	23	2
Baltimore Metro Subway	Maryland Transit Administra-tion	Baltimore, MD	14,555,100	48,000	15.5 miles	1983	14	1
PATCO Speedline	Port Authority Transit Corporation	Philadelphia, PA and Southern New Jersey	10,007,300	35,300	14.2 miles	1936	13	1
Staten Island Railway	Staten Island Railway	Staten Island (New York City, NY)	7,228,600	26,900	14 miles	1860	22	1
RTA Rapid Transit	Greater Cleveland Regional Transit Authority	Cleveland, OH	6,203,200	16,995	19 miles	1955	18	1

Source: Wikipedia, "List of United States Rapid Transit Systems by Ridership," accessed 20 February 2016, https://en.wikipedia.org/wiki/List_of_United_States_rapid_transit_systems_by_ridership.

Second Area of Review (Past Mass Transit Studies)

In 1997, the Federal Transit Administration sponsored the Transit Cooperative Research Program. This program focused on improving transit security due to the nation's growth and the need to meet mobility, environmental, and energy objective demands placed on public transit systems. The study provided information to transit agency general managers, police, and security, operations, training, and human resources staffs,

and to local police officials. It also offered information on a variety of approaches to improving transit security.[13]

This 1997 study focused on four areas:

1. The Impact of Transit Violence;

2. The Nature and Extent of Transit Crime;

3. Effective Strategies to Combat Crime; and

4. Crime and Response - this was accomplished by using case studies from across the United States.

The first area of this study focused on the Impact of Transit Violence. The American population views violent crime as a pandemic issue, as the rates of crime seem to grow each year. According to this study, the rate of violent crime increased nine times faster than the population during the last 30 years.[14] Violence and the fear of violence affect how the way we live our lives on a daily basis. Public transportation agencies are affected by the rising issue of violence on a daily basis. Personal security affects many peoples' decision to use public transportation on a daily basis.

The second area of this study focused on the Nature and Extent of Transit Crime. The definitions and classification of crimes are determined by federal laws, state criminal statutes, and local laws and ordinances. Crime reporting, measurement, analysis and comparison must meet the requirements established by the FBI's Uniform Crime Reporting system (UCR). This classification system was established in 1930 as part of a

[13] Jerome A. Needle and Renee M. Cobb, "Improving Transit Security" (Transit Cooperative Research Program), accessed 14 May 2016, http://onlinepubs.trb.org/onlinepubs/tcrp/tsyn21.pdf.

[14] Ibid.

joint effort between the International Association of the Chiefs of Police (IACP) and the Department of Justice.[15]

The Federal Transit Administration's Transit Security Program Planning Guide offers an alternative crime and offense classification scheme:

> General Security-this includes drunkenness, disorderly conduct, crowd control, drug law violations, minor sex offenses, solicitation, homelessness, miscellaneous misdemeanors/nuisances.
>
> Crimes Against Passengers-this includes robbery, theft, physical assault, and sexual assault.
>
> Crimes Against the Transit Agency-this includes fare evasion and fare theft, suicide attempts, vandalism, trespassing and physical security intrusions, theft, burglary, robbery, and attacks on personnel.
>
> Crimes Against the Public-this includes critical incidents/acts of terrorism that include hostages, hijacking, and bomb threats.[16]

The third area of this study focused on Effective Strategies to prevent and control crime and violence. This study found that transit agencies are employing seven classes of strategies: (1) uniformed officer; (2) non uniformed officers; (3) employee involvement; (4) education and information; (5) community outreach; (6) technology; and (7) architecture and design. The strategies that were most successful were mentioned first.[17]

This study revealed that the majority of transit agencies are placing their greatest reliance on technology and use of uniformed officers. More than half of the agencies surveyed reported use of technology to prevent and control crime. The technological

---

[15] Ibid.

[16] Ibid.

[17] Ibid.

methods involved using television and video monitoring, communications devices, automated ticketing and access systems, and security lighting.[18]

The fourth area of this study focused on Crime and Response. The case studies were pulled from across the United States, which involved perceptions of crime and vandalism. Findings from Houston, Texas, and Los Angeles, California are highlighted.

The first case study took place in Houston, Texas. This study focused on intensifying perceptions of crime leading to decreased ridership. The perception of crime has been a major issue for the Houston Metro System. While snatch and grabs have been problem on their bus system, and the overall Metro System has had problems with drug dealing and vandalism, actual crime has actually been much lower than the public perceives. The Houston Metro Transit Police discovered this disparity after surveying riders and comparing survey results to actual crime statistics. The disparity is powerfully illustrated by comparing actual and perceived crime in the downtown Houston area where there is a large number of Metro riders.[19]

The second case study took place in Los Angeles, California. This study focused on the spiraling cost of vandalism. The Los Angeles County Metropolitan Transit Authority operates over a 1,966 square mile area. At the time of this study, the data for 1993 was that this system served a population of over nine million and carried over 1.5 billion passengers that year. Even with its own police force, the system has an enormous problem with vandalism and graffiti. During this study, the Metro General Manager and Chief of Police created a 20-officer task force dedicated to reduce vandalism and graffiti.

[18] Ibid.

[19] Needle and Cobb, “Improving Transit Security.”

As part of this measure, the officers went undercover and videotaped these juveniles vandalizing Metro property. After acquiring videotape evidence, the officers incorporated the help of teachers and parents to assist in eliminating these acts. Another effort was that parents were to be held accountable and be charged with paying the damages incurred by their children that committed the acts of vandalism. Overall, the Los Angeles Metro Transit Police Department made significant progress in this area, but admit that more aggressive intervention early on would have kept vandalism under much better control.

Third Area of Review (Future Mass Transit Safety Improvements)

Many mass transit improvements have been recommended as accidents have occurred and studies have been conducted. As part of the 1997 Transit Cooperative Research Program, many improvements to mass transit security were recommended for systems across the United States. The primary strategy of choice of transit agency professionals that was considered the most effective was the deployment of more uniformed officers. The strategy was most successful with those officers riding trains, manning fixed posts, conducting directed patrols, and engaging in problem-solving. Target-hardening, technological strategies are considered highly effective for protecting transit passengers and property.

Other security and safety improvements were to implement Security Data Systems to where systems collect data on passenger crime, criminal offenders, crime patterns, and other functional crimes. These systems would collect and analyze criminal activity in order to deter and prevent future criminal activities. Another recommendation is that of training and training standards. It appears that some agencies do not view

training as a priority. The transit field might consider establishing mandatory training requirements, a core value and requirement of law enforcement and public safety profession. Mandatory training should also be considered for all personnel that are involved in the mass transit industry. Lastly, a System Security Program Plan would result in a benefit for all mass transit systems. This system would emphasize the security, safety, and performance of public transit agencies.[20]

Conclusion

This chapter provided research on mass transit across the United States. As the American population relies more on mass transit, it is paramount to study what safety measures are in place to protect these riders on a daily basis. As the threat of crime in America seems to increase on a daily basis, it is important to study how many systems are in use, the current safety measures in place, past incidents that have affected safety, and what are the proposed measures to improve mass transit safety in the future.

[20] Ibid.

CHAPTER 4

ANALYSIS

Introduction

There have been numerous accidents on the Washington Metro during its history, including several collisions and derailments that have caused equipment damage, injuries, and fatalities. WMATA has been criticized over the years for disregarding safety warnings and advice from experts.[21] This research covers three case studies of accidents on the WMATA Metrorail System and will focus on equipment damage, injuries, and fatalities. Review of these case studies provides a better insight on how mass transit security can be improved to protect its riders. The primary research question is: How can mass transit security in the United States (with a focus on the WMATA) be improved to protect its riders?

WMATA Case Studies

Shady Grove on 6 January 1996

At approximately 10:40 p.m., a WMATA Metrorail subway train (Number T-111) failed to come to a complete stop at the above-ground Shady Grove, Maryland passenger station the final station on the Metrorail's Red Line. As a result, the four-car train ran by the station platform and continued 470 feet into the Metrorail yard north of the station, striking a standing, unoccupied subway train that was awaiting to depart. The operator of

[21] Jo Becker and Lyndsey Layton, "Safety Warnings Often Ignored at Metro," *The Washington Post*, 6 June 2005, accessed 21 February 2016, http://www.washington post.com/wp-dyn/content/article/2005/06/05/AR2005060500968.html.

the train was fatally injured; the train’s two passengers were not injured. Total property damage estimates were upwards of $2.6 million dollars.[22]

Events leading up to this accident included a winter storm warning issued by the National Weather Service at 6:40 a.m. on Saturday, 6 January 1996. The warning extended through Saturday night and into Sunday was for northern Virginia and central and southern Maryland, including the Washington, DC Metropolitan area. The snow was expected to begin Saturday evening, becoming heavy at times after midnight, and to continue through Sunday. Total snow accumulations were expected to exceed 12 inches in many locations. According to Safety Board interviews, WMATA prepared for the predicted adverse weather by opening its snow command center at WMATA Headquarters at 5:00 p.m. on 6 January and by holding a “snow meeting” of managers and supervisors that evening.

[22] National Transportation Safety Board, *Railroad Accident Report* (January 1996).

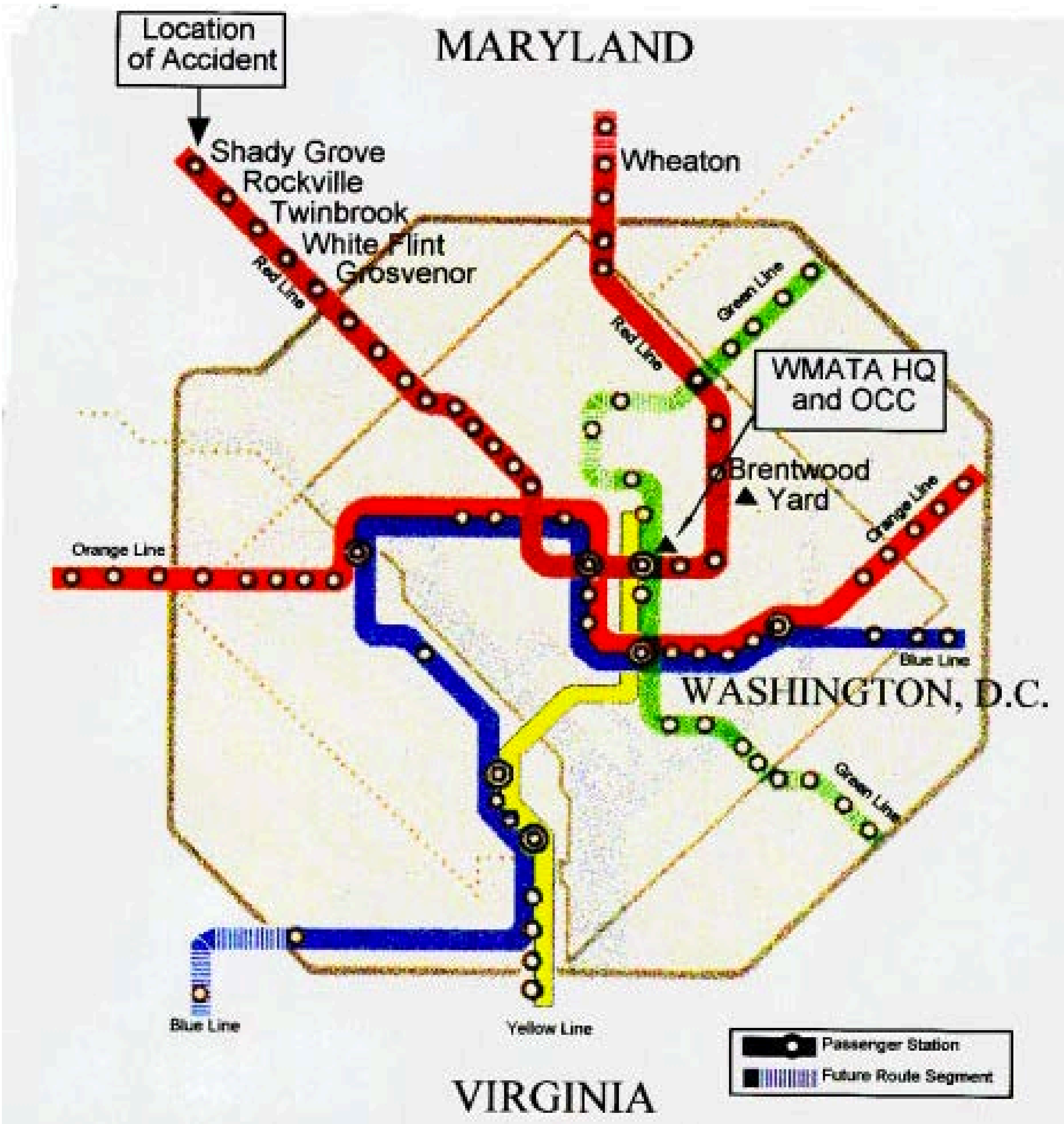

Figure 2. Schematic Representation of the Washington, DC, Metrorail System with Selected Locations Identified during Shady Grove Accident

Source: National Transportation Safety Board, *Railroad Accident Report* (Washington, DC: National Transportation Safety Board, January 1996), accessed 21 February 2016, http://www.ntsb.gov/investigations/AccidentReports/Reports/RAR9604.pdf.

At 10:18 p.m., the operator of the Train T-110 (the train immediately preceding accident Train T-111) reported to the Red Line Operations Control Center (OCC) radio controller that slippery tracks had caused his train to overrun the Twinbrook Station platform by one car. The controller instructed the operator of Train T-110 to continue to operate in automatic mode.

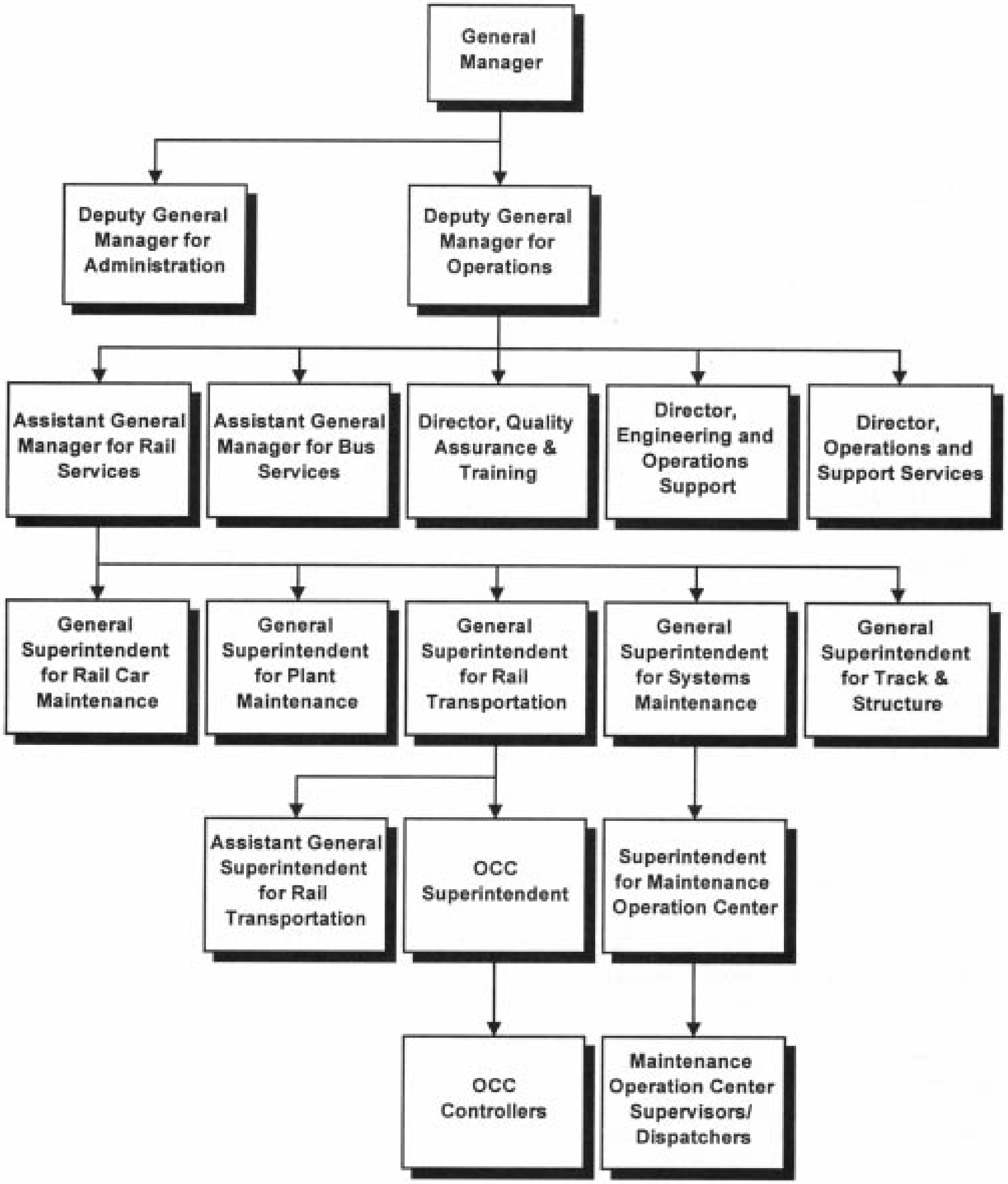

Figure 3. Selected Elements of WMATA Organizational Structure with Emphasis on Metrorail Management

Source: National Transportation Safety Board, *Railroad Accident Report* (Washington, DC: National Transportation Safety Board, January 1996), accessed 21 February 2016, http://www.ntsb.gov/investigations/AccidentReports/Reports/RAR9604.pdf.

Train Damage: Car 3252, the lead car of Train T-111, sustained the most extensive damage. The shell of the car became partially disengaged from the frame and came to rest partially on top of the lead car of the gap train. Car 3191, the lead car of the gap train, sustained a uniform crush of approximately 10 inches across the front of the car. The remaining cars of Train T-111 and the gap train received only minor damages. Total estimated damages were between $2.1 and $2.6 million.[23]

Both Train T-111 and the gap train consisted of railcars manufactured by the Italian firm of Breda Costruzoni Ferroviarie, S.p.A., and were among the 466 Breda cars owned by WMATA and operated on the Metrorail system at the time. Each car involved was 75 feet long and 10 feet wide and weighed approximately 37 tons. The cars could seat 68 passengers each, with standing room for an additional 119, for a total passenger capacity of 187. Like all cars on the Metrorail system, each car was propelled by four traction motors receiving power from an electrified "third rail." All Metrorail carbodies are constructed primarily of aluminum extrusions that serve both as structural components and as exterior skin for the roof, side walls, and rear-end cowl.

[23] National Transportation Safety Board, *Railroad Accident Report* (January 1996).

Figure 4. Final Train Positions of the 6 January 1996 Accident at the Shady Grove Station

Source: National Transportation Safety Board, *Railroad Accident Report* (Washington, DC: National Transportation Safety Board, January 1996), accessed 21 February 2016, http://www.ntsb.gov/investigations/AccidentReports/Reports/RAR9604.pdf.

Figure 5. Figure 5. Head end of Train T-111 during Shady Grove Accident, where Operator's Unit was Completely Crushed

Source: National Transportation Safety Board, *Railroad Accident Report* (Washington, DC: National Transportation Safety Board, January 1996), accessed 21 February 2016, http://www.ntsb.gov/investigations/AccidentReports/Reports/RAR9604.pdf.

National Transportation Safety Board Conclusions[24]

The NTSB concluded the following in regards to the Shady Grove accident investigation.

[24] National Transportation Safety Board, *Railroad Accident Report* (January 1996).

Neither fatigue nor track and signal operations were causal or contributing factors in the accident.

WMATA's decision to completely and suddenly replace its policy of intermittent routine manual train operation with an essentially untested policy of full-time automatic 'train operation was a hasty decision based on insufficient information.

Before making the decision to eliminate manual train operation on the Metrorail system, WMATA failed to consider the continuing need for train operators to maintain proficiency in manual train operation.

Metrorail management failed to fully understand the design features and limitations of the automatic train control (ATC) system, which led to unjustified management confidence that the system could ensure safe train operation under all operating conditions.

The WMATA management, prior to the accident, did not have a well-thought-out, firmly established maximum authorized speed policy that was understood and followed by all operating department employees.

At the time of the accident, WMATA was using the non-safety-critical automatic train supervision subsystem to perform safety-critical functions.

The 17 November 1995, notice instructing OCC controllers that they were not to permit train operators to change from automatic to manual mode constituted a change to *Metrorail Safety Rules and Procedures Handbook* rule 3.85, and in issuing the notice, WMATA management failed to comply with its own established formal procedures for making changes to operating rules.

If WMATA management had initially issued written, rather than oral, instructions regarding the safe placement of gap trains and had ensured that this policy was known and followed, the gap train at Shady Grove would probably not have been located where it was on the night of the accident, and the collision would not have occurred.

The WMATA management relies too heavily on oral instructions to convey operations and safety information to its managers, supervisors, and employees.

The WMATA management and its board of directors, at the time of this accident, was not providing adequate direction to ensure safety on the Metrorail system.

As demonstrated by this accident, the training given to OCC controllers by WMATA prior to the accident was inadequate to prepare them to safely manage and control the highly automated Metrorail system.

Operations Control Center controllers, and, to a degree, their immediate supervisors, had responsibility for day-to-day train operations, but they lacked the authority and the systematic procedures necessary to effectively carry out that responsibility.

The deficient performance of the OCC on the night of the accident resulted from top-level WMATA management policies and decisions in that Metrorail management did not create an environment in which controllers were encouraged to use their own experience, knowledge, and judgment to make decisions involving the safety of Metrorail operations.

The failure of the rescue commander at the accident scene to immediately establish a direct command link with the OCC caused miscommunications and delays in de-energizing the third rail that unnecessarily put firefighters at risk.

The WMATA acted improperly when it did not halt train traffic into Shady Grove and turn off third-rail power in the accident area immediately after the OCC was notified of the collision.

Because WMATA management has not viewed station overruns as a potential safety issue, it has not taken the adequate steps to identify and eliminate the cause of the 400 to 450 station or platform overruns experienced each year on the Metrorail system.

National Transportation Safety Board Probable Cause

The NTSB deemed the probable cause of the Shady Grove accident[25] as follows: The Safety Board determines that the probable cause of this accident was the failure of the WMATA management and board of directors;

1. to fully understand and address the design features and incompatibilities of the ATC system before establishing automatic train operation as the standard operating mode at all times and in all weather conditions,

2. to permit operating department employees, particularly OCC controllers and supervisors, to use their own experience, knowledge, and judgment to make decisions involving the safety of Metrorail operations, and

3. to effectively promulgate and enforce a prohibition against placing standby trains at terminal stations on the same track as incoming trains. Contributing to the severity of the injuries to the train operator was the disproportionate amount of crush sustained by the lead cars of the colliding trains.

[25] National Transportation Safety Board, *Railroad Accident Report* (January 1996).

National Transportation Safety Board Recommendations[26]

The NTSB provided the following recommendations to WMATA, the Federal Transit Administration, the Montgomery County Fire and Rescue Commission, and to all jurisdictions providing primary or secondary response to Metrorail incidents following the Shady Grove accident.

To WMATA

Analyze the braking performance under low-adhesion conditions of all railcar series in the Metrorail fleet. Take the measures necessary to ensure compatibility between the cars' braking performance and the ATC system block design.

Discontinue the use of the non-vital and non-fail-safe automatic train supervision (ATS) subsystem to perform safety critical functions, and make it impossible for trains to default to a higher speed when a lower speed is required to ensure safe operation.

Establish, document, and enforce a maximum authorized speed for every route segment on the Metrorail system. Ensure that these speeds are made known to all Metrorail personnel who hold safety-sensitive positions.

Implement policies and procedures that provide a means for train operators to develop and maintain proficiency in manual train operation.

Conduct a detailed investigation and analysis to determine the cause of the approximately 400 station or platform overruns experienced across the Metrorail system each year, and take the measures necessary to improve train stopping accuracy and to eliminate station overruns.

---

[26] Ibid.

Finalize the specifications for a new advanced technology carborne monitoring system and, once that is complete, retrofit existing Metrorail cars with the monitors (recorders) during rehabilitation and require that all new Metrorail cars be equipped with the devices.

Amend WMATA standard operating procedures to require that in Metrorail emergencies in which rescue workers must be summoned to the scene or in which the possibility of passenger evacuation exists, all train traffic be diverted from that location as soon as possible and all third-rail circuits in the emergency area, including those on adjacent tracks, be de-energized as soon as trains have left the vicinity.

Develop a mechanism to provide emergency rescue personnel responding to an accident anywhere on the Metrorail system with easily accessible information about third-rail circuitry. Such a mechanism could include or consist of posting schematics or third rail circuit diagrams on all blue light boxes and fences adjacent to interlockings.

Implement a program of regularly scheduled operational testing of systems used to remotely trip third-rail circuit breakers from OCC command consoles.

To the Federal Transit Administration

Develop, with the assistance of the American Public Transit Association, guidelines for monitoring (recording) devices that capture critical performance and event data for rapid rail transit cars and urge transit agencies to install these devices on new and rehabilitated cars.

To the American Public Transit Association

Cooperate with the Federal Transit Administration in developing guidelines for monitoring (recording) devices that capture critical performance and event data for rapid rail transit cars and urge transit agencies to install these devices on new and rehabilitated cars.

To the Montgomery County Fire and Rescue Commission

Review your Metrorail Standard Operating Procedures regarding the requirement that the on-scene rescue commander immediately take charge of the accident scene and establish a direct communications link with the Metrorail Operations Control Center. Ensure that all rescue personnel and supervisors are knowledgeable about the procedure and are trained to carry it out.

To all Jurisdictions Providing Primary or Secondary
Response to Metrorail Accidents or Incidents

Review the circumstances of this accident, with particular attention to deficiencies in emergency response procedures. Review and amend, as necessary, your risk assessment procedures and emergency response plans and procedures for responding to Metrorail accidents or incidents.

Investigation[27]

The NTSB learned of this accident on 6 January 1996. Investigation by telephone began immediately. The winter storm delayed the dispatch of an on scene investigator from the Safety Board's Washington, DC, headquarters until 11 January 1996. Additional

[27] National Transportation Safety Board, *Railroad Accident Report* (January 1996).

investigators were dispatched later to participate in the on-scene investigation. Investigators began taking testimony on 16 January 1996.

This report is based on the factual information developed as a result of the investigation and on Safety Board analysis. The Safety Board has considered all facts in the investigative record relative to its statutory responsibility to determine probable cause of the accident and to make recommendations.

The following parties participated in this investigation: Washington Area Metropolitan Transit Authority, Westinghouse Air Brake Company, and the Rockville (Maryland) Volunteer Fire Department.

The Safety Board did not conduct a public hearing during this investigation.

Woodley Park on 3 November 2004

An out of service Red Line train rolled backwards into the Woodley Park Station and hit an in-service train that was at the platform servicing the station.[28]

This had no fatalities, but 20 personnel were injured.[29]

On Wednesday, 3 November 2004, about 12:49 p.m., eastern standard time, WMATA Metrorail Train 703 collided with Train 105 at the Woodley Park-Zoo-Adams Morgan station in Washington, DC Train 703 was traveling outbound on the Red-Line segment of the Metrorail system and ascending the grade between the Woodley Park-

[28] National Transportation Safety Board, *NTSB Railroad Accident Report–2004 Woodley Park Accident* (Washington, DC: National Transportation Safety Board, November 2004), accessed 11 April 2016, http://www.ntsb.gov/investigations/AccidentReports/Reports/RAR0601.pdf.

[29] Lyndsey Layton and Steven Ginsberg, “20 Injured in Crash of 2 Red Line Trains,” *The Washington Post*, 4 November 2004, A01, accessed 10 April 2016, http://www.washingtonpost.com/wp-dyn/articles/A22466-2004Nov3.html.

Zoo-Adams Morgan and the Cleveland Park underground stations, when it rolled backwards about 2,246 feet and struck Train 105 at a speed of about 36 mph. Train 703 was operating as a nonrevenue train; that is, it was not carrying passengers. Train 105, a revenue train, was in the process of discharging and loading passengers at the Woodley Park-Zoo-Adams Morgan station. There were about 70 passengers on board Train 105. Some passengers had exited the train just before or during the collision. The District of Columbia Fire and Emergency Medical Service transported about 20 persons to local hospitals. Estimated property damages were $3,463,183.[30]

Events leading up to the accident focused on the two train operators. On the day of the accident, the operator of train 703 started work about 8:00 a.m. at Shady Grove Station. He stated that this was an overtime shift during which he was to work as assigned until about 1:00 p.m. and then start his regular work shift later that afternoon. The operator normally worked the 2:00 p.m. to 11:00 p.m. shift, but on this day he signed up for overtime to work the 8:00 a.m. to 1:00 p.m. shift prior to working his regular shift. His first assignment was Train 156, a revenue train traveling from Shady Grove to Glenmont, which are stations located on opposite ends of the Red Line. The train was operated in the automatic mode for the morning trip. At the DuPont Circle Station, a WMATA supervisor for the Red Line boarded the train and performed an unannounced inspection of the train operator's performance, from DuPont Circle to the Gallery Place-Chinatown Station. Upon completion of the quality check, the supervisor departed the train without comment.

[30] Ibid.

Train 156 arrived at the Glenmont station, and the operator was informed that he would make a return trip with the same equipment to Shady Grove as Train 103. When he arrived at the Friendship Heights Station, a supervisor boarded his train and performed another quality check for the ride to the Shady Grove Station. When he arrived at Shady Grove, the operator said that a supervisor told him to take a 6-car nonrevenue train to the maintenance facility at Brentwood. Specifically, he was told to leave four cars on track five and retrieve four cars from track three. He was expected to return to Shady Grove with Train 703, a 6-car nonrevenue service train. After completing his work at Brentwood, the operator of Train 703 received instructions from the OCC to enter the mainline at Brentwood Yard and follow Train 203, a revenue service train, back to Shady Grove. Train 105, another revenue service train, was to follow him. The operator of Train 703 stated that he operated the train in manual mode, which is controlled by the train operator as required for a nonrevenue train move, on the trip back to Shady Grove. He stated that he was getting ringer alarms for travelling over speed frequently during the trip. Every time he received a ringer, he said that he had to brake his train by placing the master controller into the proper braking position. This slowed the train to the proper allowable track speed and silenced the ringer.

When asked about the collision, the operator of Train 703 told investigators that he passed through the Woodley Park Station at the required speed of 25 mph. In accordance with the operating rules, he sounded the horn but did not stop the train. He stated that he could see a train ahead at the Cleveland Park Station platform, and he received an alarm as he ascended the grade approaching the station. He stated that he placed the master controller in the proper braking position to slow his train and quiet the

ringer. About 12:49 p.m., Train 703 rolled backwards about 2,246 feet downhill for about 78 seconds and collided with Train 105, which was stopped at the outbound platform the Woodley Park Station, where passengers were boarding and exiting the train. The operator was the only employee on board Train 703 when the collision occurred.

Figure 6. Woodley Park Station Accident Locations

Source: National Transportation Safety Board, *NTSB Railroad Accident Report–2004 Woodley Park Accident* (Washington, DC: National Transportation Safety Board, November 2004), accessed 11 April 2016, http://www.ntsb.gov/investigations/AccidentReports/Reports/RAR0601.pdf.

Figure 7. Train 703 Resting on Top of Train 105

Source: National Transportation Safety Board, *NTSB Railroad Accident Report–2004 Woodley Park Accident* (Washington, DC: National Transportation Safety Board, November 2004), accessed 11 April 2016, http://www.ntsb.gov/investigations/AccidentReports/Reports/RAR0601.pdf.

Table 2. Injuries Sustained in Accident

Type	Train 105*	Train 703	Total
Fatal	0	0	0
Serious	1	0	1
Minor	19	0	19
None	52	1	53
Total	72	1	73

*The total in this column is an estimate based on witness statements.

Source: National Transportation Safety Board, *NTSB Railroad Accident Report–2004 Woodley Park Accident* (Washington, DC: National Transportation Safety Board, November 2004), accessed 11 April 2016, http://www.ntsb.gov/investigations/AccidentReports/Reports/RAR0601.pdf.

Title 49 Code of Federal Regulations 830.2 defines fatal injury as "any injury which results in death within 30 days of the accident" and serious injury as "an injury which:

> 1. requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received;
>
> 2. results in a fracture of any bone (except simple fractures of fingers, toes, or nose);
>
> 3. causes severe hemorrhages, nerve, or tendon damage;
>
> 4. involves any internal organ; or
>
> 5. involves second-or third-degree burns, or any burn affecting more than 5 percent of the body surface."

National Transportation Safety Board Conclusions[31]

The NTSB concluded the following in regards to the Woodley Park Station accident investigation.

The track, signal, and communications systems were not factors in this accident.

The use of drugs or alcohol was not a factor in this accident.

The emergency response to the accident was well coordinated and effectively managed.

The braking systems of Train 703 were operable on the day of the accident and, if applied, could have stopped the train.

If the equipment on Train 703 had been equipped with a rollback protection feature in the manual mode, the train could have been safely stopped, regardless of the train operator's action or inaction, and the accident could have been prevented.

The WMATA was unaware, at the time of the accident, that the rollback protection feature was generally not available when a train was operated in the manual mode, and consequently no specific training was provided to operators about the lack of this feature on all cars.

The low task demands and unremarkable operating environment during the accident trip were conducive to the train operator becoming disengaged from some critical train operations.

The train operator's alertness was likely reduced due to inadequate sleep.

---

[31] National Transportation Safety Board, *NTSB Railroad Accident Report–2004 Woodley Park Accident*.

The WMATA's practice of allowing train operators to return to work after having as few as eight hours off between shifts following prolonged tours of duty does not give train operators the opportunity to receive adequate sleep to be fully alert and to operate safely.

Emergency access-egress points for the WMATA's equipment do not provide adequate means for emergency responder entry or passenger evacuation.

The failure of the carbody (underframe) end structure of the 1000-series Metrorail cars may make them susceptible to telescoping and potentially subject to a catastrophic compromise of the occupant survival space.

The failure to have minimum crashworthiness standards for preventing telescoping of rail transit cars in collisions place an unnecessary risk on passengers and crew.

National Transportation Safety Board Probable Cause[32]

The NTSB determines that the probable cause of the 3 November 2004 collision between two WMATA trains at the Woodley Park-Zoo-Adams Morgan Station was the failure of the operator of Train 703 to apply the brakes to stop the train, likely due to his reduced alertness. Contributing to the accident was the lack of a rollback protection feature to stop the train when operated in the manual mode.

[32] National Transportation Safety Board, *NTSB Railroad Accident Report–2004 Woodley Park Accident*.

National Transportation Safety Board Recommendations[33]

The NTSB provided the following recommendations to WMATA and the Federal Transit Administration following the Woodley Park Station accident:

To WMATA

Equip, as soon as possible, all existing and future train equipment with rollback protection for trains operated in the manual mode.

Either accelerate retirement of Rohr-built railcars, or if those railcars are not retired but instead rehabilitated, then Rohr-built passenger railcars should incorporate a retrofit of crashworthiness collision protection that is comparable to the 6000-series railcars.

Immediately revise the directions to train operators contained in memorandums dated 7 and 9 November 2004, to include specific written instructions for identifying and responding to an emergency rollback situation, and provide training to operators on the procedures to follow if such a rollback event occurs.

To the Federal Transit Administration

Require transit agencies, through the system safety program and hazard management process if necessary, to ensure that the time off between daily tours of duty, including regular and overtime assignments, allows train operators to obtain at least eight hours of uninterrupted sleep.

Assess the adequacy of the WMATA's current organizational structure and ensure that it effectively identifies and addresses safety issues.

[33] Ibid.

Develop transit railcar design standards to provide adequate means for safe and rapid emergency responder entry and passenger evacuation.

Develop minimum crashworthiness standards to prevent the telescoping of transit railcars in collisions and establish a timetable for removing equipment that cannot be modified to meet the new standards.

Investigation[34]

The NTSB was notified of the collision between two Washington Area Metropolitan Transit Authority trains about 2:18 p.m., eastern standard time, on 3 November 2004. An investigative team was dispatched with members from the Safety Board's Washington, DC, headquarters and its Los Angeles, California, regional office. The team included investigative groups for transit operations, track, and oversight; mechanical; human performance; survival factors and emergency response; event recorders; and crashworthiness. The Office of Public Affairs assisted with the on-scene public-media relations.

Parties to the on-scene investigation included the Washington Area Metropolitan Transit Authority, the District of Columbia Fire Department, and the Tri-State Oversight Committee.

Fort Totten on 22 June 2009

On Monday, 22 June 2009, at approximately 4:58 p.m., eastern daylight time, inbound WMATA Metrorail Train 112 struck the rear of stopped inbound Metrorail Train

[34] National Transportation Safety Board, *NTSB Railroad Accident Report–2004 Woodley Park Accident*.

214. The accident occurred on aboveground track on the Metrorail Red Line near the Fort Totten Station in Washington, DC. The lead car of Train 112 struck the rear car of Train 214, causing the rear car of Train 214 to telescope into the lead car of Train 112, resulting in a loss of occupant survival space in the lead car of about 63 feet (about 84 percent of its total length). Nine people aboard Train 112, including the train operator, were killed. Emergency response agencies reported transporting 52 people to local hospitals. Damage to train equipment was estimated to be $12 million.[35]

On the day of the accident, the operator of Train 214 (the struck train) reported for the second part of his tour of duty for the day at the Shady Grove Station at 3:28 p.m. His first afternoon assignment was to operate Red Line Train 214 from Shady Grove to Silver Spring (See map below). At the time of the accident, he was on his second trip of the afternoon, which consisted of operating Red Line Train 214, with six cars, from Silver Spring to Grosvenor-Strathmore.

[35] National Transportation Safety Board, *Railroad Accident Report* (Washington, D.C: National Transportation Safety Board, 27 July 2010), accessed 11 April 2016, http://www.ntsb.gov/investigations/AccidentReports/Reports/RAR1002.pdf.

Figure 8. Fort Totten Station Accident Locations

Source: National Transportation Safety Board, *Railroad Accident Report* (Washington, D.C: National Transportation Safety Board, 27 July 2010), accessed 11 April 2016, http://www.ntsb.gov/investigations/AccidentReports/Reports/RAR1002.pdf.

Figure 9. Lead Car of Striking Train (Train 112) has Overridden the Last Car of Struck Train (Train 214), which has Telescoped into the Lead Car of Train 112

Source: National Transportation Safety Board, *Railroad Accident Report* (Washington, D.C: National Transportation Safety Board, 27 July 2010), accessed 11 April 2016, http://www.ntsb.gov/investigations/AccidentReports/Reports/RAR1002.pdf.

The operator of Train 112 (the striking train) reported for duty at Brentwood Yard at 3:50 p.m. Her first assignment was to operate Red Line Train 112, also with six cars, from Silver Spring to Shady Grove. She was to depart Silver Spring at 4:33 p.m., following Train 214 on the inbound track travelling south towards Metro Center. The operator of Train 214 said that he was operating his train in manual mode when he departed Glenmont and that his trip was uneventful until after he departed the Takoma

Station en route to the next station stop at Fort Totten. Because of an earlier equipment problem with one of the inbound Red Line Trains, train traffic was congested, and Train 214 was following closely behind Train 110. The operator said that he had been slowing his train multiple times because of the presence of Train 110. He said that as his train traveled between the Takoma and Fort Totten Stations, it "lost speed commands" (meaning that the readouts on the operator's console showed an authorized speed of 0 mph), which caused the train to stop. The operator said that he attributed the loss of speed commands to the proximity of his train to Train 110, which was at the Fort Totten Station platform at the time. The operator said he expected the speed commands to return momentarily (as soon as Train 110 moved out of the station).

Meanwhile, Train 112, being operated in automatic mode, was traveling behind Train 214. A passenger on Train 112 recalled that after leaving the Takoma Station, the train stopped, and the operator announced over the train's public address system that another train (which was Train 214) was ahead and that they would be moving shortly. The passenger said that the train stopped only briefly, after which it began to move forward and to accelerate to what the passenger estimated was "top speed." Maximum speed for that track segment was 55 mph. (According to recorded train control system data, the speed commands that should have been transmitted to Train 112 dropped from 55 mph to 0 mph at 4:56:41. About 39 seconds later, at 4:57:20, speed commands resumed at 55 mph.). The operator of Train 214 said that, after being stopped for what he described as a short time, he felt a "big push" and heard noise toward the rear of his train. He said he noticed that his operator's console had lost power. Recorded data indicate that third-rail power was lost at 4:58:08 (The 750-volt third rail provides power to the trains).

The Train 214 operator said that as he walked through the cars toward the rear of the train, he saw a number of passengers who had been knocked from their seats by the impact. He said he tried to use his portable radio and cellular (cell) phone to contact the Metrorail OCC, but the attempt was unsuccessful. (It was later determined that OCC personnel could hear the operator, but the operator was unable to hear their responses.) The operator said that when he reached the fourth or fifth car in his train, he encountered smoke. After asking the passengers to move forward on the train, he used the emergency release lever in the car to open a side door, from which he jumped to the ground. Once on the ground and among injured passengers alongside the trains, he successfully established communications with the OCC and reported the collision. He also asked that electrical power to the third rail be cut because of passengers on the ground in the area. He requested emergency medical assistance and then boarded the train again to help injured and trapped passengers.

The operator of Train 112 was found fatally injured in the train control compartment. The emergency brake button was found in the depressed position. She did not appear to have attempted to leave the control compartment before the collision, and a review of recordings of radio transmissions showed that she had not made a radio call in the moments leading up to the accident.

<u>National Transportation Safety Board Conclusions</u>[36]

The NTSB concluded the following in regards to the Fort Totten Station accident investigation:

---

[36] National Transportation Safety Board, *Railroad Accident Report* (27 July 2010).

The following were neither causal nor contributory to the accident: weather, training and qualifications of the train operators, fatigue, use of alcohol or illegal drugs by the train operators, track structure and rail integrity, and condition and performance of train mechanical equipment.

The operator's decision to operate Train 214 (the struck train) in manual mode during the evening rush hour period was in violation of Metrorail rules, but track circuit B2-304 was failing to detect trains, regardless of whether they were operating in manual or automatic mode.

Because Train 214, which was being operated in manual mode, was traveling at a much slower speed than the authorized speed commands it was receiving, Train 214 stopped completely within the faulty B2-304 track circuit when its detection was lost and it received a 0 mph speed command.

Because of the design of the WMATA OCC information management system and the high number of track circuit failure alarms routinely generated by that system, OCC controllers could not have been expected to be aware of the impending collision or to warn either train operator.

Considering the challenges of the recovery operations, the emergency response was well coordinated and effectively managed.

The Metrorail ATC system stopped detecting the presence of Train 214 (the struck train) in track circuit B2-304, which caused Train 214 to stop and also allowed speed commands to be transmitted to Train 112 (the striking train) until the collision.

Even though the operator of Train 112 activated emergency braking before the collision, there was not enough time, once Train 214 came into full view, to stop the train and avoid a collision.

On the day of the accident, parasitic oscillation in the track circuit modules for track circuit B2-304 was creating a spurious signal that mimicked a valid track circuit signal, thus causing the track circuit to fail to detect the presence of Train 214.

Spurious signals had been causing the track circuit modules for track circuit B2-304 to erroneously indicate that the track circuit was vacant from the time the track circuit transmitter power was increased after the impedance bond was replaced on 17 June 2009, until the accident five days later.

Train operators did not report problems with track circuit B2-304 before the accident because reductions in speed commands to maintain train separation, or even momentary losses of all speed commands, were common during train operations.

National Transportation Safety Board Probable Cause[37]

The NTSB determines that the probable cause of the 22 June 2009, collision of WMATA Metrorail Train 112 with the rear of standing Train 214 near the Fort Totten station was;

1. a failure of the track circuit modules, built by GRS-Alstom Signaling Inc., that caused the ATC system to lose detection of Train 214 (the struck train) and thus transmit speed commands to Train 112 (the striking train) up to the point of impact, and

[37] National Transportation Safety Board, *Railroad Accident Report* (27 July 2010).

2. WMATA's failure to ensure that the enhanced track circuit verification test (developed following the 2005 Rosslyn near-collisions) was institutionalized and used system wide, which would have identified the faulty track circuit before the accident.

Contributing to the accident were;

1. WMATA's lack of a safety culture,

2. WMATA's failure to effectively maintain and monitor the performance of its ATC system,

3. GRS-Alstom Signaling Inc.'s failure to provide a maintenance plan to detect spurious signals that could cause its track circuit modules to malfunction,

4. ineffective safety oversight by the WMATA Board of Directors,

5. the Tri-State Oversight Committee's ineffective oversight and lack of safety oversight authority, and

6. the Federal Transit Administration's lack of statutory authority to provide federal safety oversight.

Contributing to the severity of passenger injuries and the number of fatalities was WMATA's failure to replace or retrofit the 1000-series railcars after these cars were shown in a previous accident to exhibit poor crashworthiness.

National Transportation Safety Board Recommendations[38]

The NTSB provided the following recommendations to WMATA, the WMATA Board of Directors, the Federal Transit Administration, the U.S. Department of

[38] National Transportation Safety Board, *Railroad Accident Report* (27 July 2010).

Transportation, the Tri-State Oversight Committee, to Alstom Signaling Inc., and other regional transportation authorities following the Fort Totten Station accident:

To WMATA

Because of the susceptibility to pulse-type parasitic oscillation that can cause a loss of train detection by the Generation 2 General Railway Signal Company audio frequency track circuit modules, establish a program to permanently remove from service all of these modules within the Metrorail system.

Establish periodic inspection and maintenance procedures to examine all audio frequency track circuit modules within the Metrorail system to identify and remove from service any modules that exhibit pulse-type parasitic oscillation.

Completely remove the unnecessary Metrorail wayside maintenance communication system to eliminate its potential for interfering with the proper functioning of the train control system.

Conduct a comprehensive safety analysis of the Metrorail ATC system to evaluate all foreseeable failures of this system that could result in a loss of train separation, and work with your train control equipment manufacturers to address in that analysis all potential failure modes that could cause a loss of train detection, including parasitic oscillation, cable faults and placement, and corrugated rail.

Implement cable insulation resistance testing as part of Metrorail's periodic maintenance program.

Develop and implement a non-punitive safety reporting program to collect reports from employees in all divisions within your organization, and ensure that the safety department; representatives of the operations, maintenance, and engineering departments;

and representatives of labor organizations regularly review these reports and share the results of those reviews across all divisions of your organization.

Review the Hazard Identification and Resolution Matrix process in your system safety program plan to ensure that safety-critical systems such as the ATC system and its subsystem components are assigned appropriate levels of risk in light of the issues identified in this accident.

Remove all 1000-series railcars as soon as possible and replace them with cars that have crashworthiness collision protection at least comparable to the 6000-series railcars.

Ensure that the lead married-pair car set of each train is equipped with an operating onboard event recorder.

Develop and implement a program to monitor the performance of onboard event recorders and ensure they are functioning properly.

To the WMATA Board of Directors

Elevate the safety oversight role of the WMATA Board of Directors by;

1. Developing a policy statement to explicitly and publicly assume the responsibility for continual oversight of system safety,

2. Implementing processes to exercise oversight of system safety, including appropriate proactive performance metrics, and

3. Evaluating actions taken in response to NTSB and Federal Transit Administration recommendations, as well as the status of open corrective action plans and the results of audits conducted by the Tri-State Oversight Committee.

To the Federal Transit Administration

Facilitate the development of non-punitive safety reporting programs at all transit agencies to collect reports from employees in all divisions within their agencies and to have their safety departments; representatives of their operations, maintenance, and engineering departments; and representatives of labor organizations regularly review these reports and share the results of those reviews across all divisions of their agencies.

Seek authority similar to Federal Railroad Administration regulations (Title 49 Code of Federal Regulations 219.207) to require that transit agencies obtain toxicological specimens from covered transit employees and contractors who are fatally injured as a result of an on-duty accident.

To the U.S. Department of Transportation

Continue to seek the authority to provide safety oversight of rail fixed guideway transportation systems, including the ability to promulgate and enforce safety regulations and minimum requirements governing operations, track and equipment, and signal and train control systems.

To the Tri-State Oversight Committee

Work with the WMATA to satisfactorily address the recommendations contained in the Federal Transit Administration's 4 March 2010, final report of its audit of the Tri-State Oversight Committee and the WMATA.

To Alstom Signaling Inc

Develop and implement periodic inspection and maintenance guidelines for use by the WMATA and other rail transit operators and railroads equipped with General

Railway Signal Company audio frequency track circuit modules and assist them in identifying and removing from service all modules that exhibit pulse-type parasitic oscillation in order to ensure the vitality and integrity of the ATC system.

Conduct a comprehensive safety analysis of your audio frequency track circuit modules to evaluate all foreseeable failure modes that could cause a loss of train detection over the service life of the modules, including parasitic oscillation, and work with your customers to address these failure modes.

To the Massachusetts Bay Transportation Authority, the Southeastern Pennsylvania Transportation Authority, the Greater Cleveland Regional Transit Authority, the Metropolitan Atlanta Regional Transportation Authority, the Los Angeles County Metropolitan Transportation Authority, and the Chicago Transit Authority

Work with Alstom Signaling Inc. to establish periodic inspection and maintenance procedures to examine all General Railway Signal Company audio frequency track circuit modules to identify and remove from service any modules that exhibit pulse-type parasitic oscillation.

Investigation[39]

The NTSB was notified of the accident about 5:30 p.m. on 22 June 2009. The investigator-in-charge and other members of the NTSB investigative team were launched from the headquarters office in Washington, DC, and from field offices in Chicago, Illinois, and Gardena, California. The NTSB's investigation focused on all aspects of the accident, including signal and train control, operations, track, mechanical issues, human

[39] National Transportation Safety Board, *Railroad Accident Report* (27 July 2010).

performance, survival factors, crashworthiness, event recorders, and safety culture-oversight issues.

Parties to the investigation were the Federal Transit Administration, the Federal Railroad Administration, the WMATA , the Amalgamated Transit Union, the Tri-State Oversight Committee, the District of Columbia Fire and Emergency Medical Services Department, Alstom Signaling Inc., and Ansaldo STS USA.

A public hearing on this accident was held at the NTSB Conference Center in Washington, DC, 23 to 26 February 2010.

Analysis of Case Studies

The three accidents studied occurred throughout a 13 year timeframe. Each accident occurred at different times throughout the year. The three accident studied had different contributing factors, as to give the research a variety of accidents and outcomes. The five factors used to analyze the cases studied were: (1) The Loss of Life; (2) Injuries Suffered; (3) Loss of Equipment; (4) Equipment Failure; and (5) Operator Error. These five factors were selected as they were each addressed by the NTSB as part of their independent studies. These five factors are important when studying Metrorail accidents as they are detrimental to mass transit rider safety.

Table 3. Analysis of Case Study Factors

Factors Used for Analysis	Case Study #1 Shady Grove	Case Study #2 Woodley Park	Case Study #3 Fort Totten
Loss of Life	+	-	+
Injuries Suffered	+	+	+
Loss of Equipment	+	+	+
Equipment Failure	-	+	+
Operator Error	-	+	-

Source: Created by Author
Note: + Positive Outcome of this factor in relation to the case study evaluated
- Negative Outcome of this factor in relation to the case study evaluated

Loss of Life

A loss of life is a critical factor in any type of accident. Within the three case studies that were researched, the Shady Grove and Fort Totten Accidents resulted in the loss of at least one life per accident. The Shady Grove Accident resulted in one person losing their life, the train operator of Train T-111. The Fort Totten Accident resulted in nine people losing their life, including the train operator of Train 112, and many more sustaining injuries.

Injuries Suffered

Injuries play a major role in the outcomes and severity of accidents. Injuries were suffered in all three case studies that were researched. As mentioned above, The Shady Grove Accident resulted in one fatal injury, none of the other riders were injured. The Woodley Park Accident resulted in 20 injuries, after which local first responders transported the injured passenger to local hospitals. As earlier noted, The Fort Totten

Accident resulted in nine fatalities and 52 people were injured and transported to local hospitals for care.

Loss of Equipment

Loss of equipment can result in lost revenue and overall effectiveness of Metrorail Systems. All of the cases studied during this research had a significant amount of loss of equipment. However, the cost amount produced by each accident is what is substantial in this research. The Shady Grove Accident resulted in loss of equipment and damages that were estimated between $2.1 and $2.6 million dollars. The Woodley Park Accident resulted in loss of equipment and damages that were estimated at $3.5 million dollars. The Fort Totten Accident resulted in loss of equipment and damages that were estimated at $12 million dollars.

Equipment Failure

The Fort Totten Accident was the only case study in this research that was the result of equipment failure. As previously noted, the probable cause of this accident was the failure of the track circuit modules and WMATA's failure to ensure that the enhanced track circuit verification test was institutionalized and used system wide, which would have identified the faulty track circuit before the accident. However, even though it was not the main factor, a contributing factor in the Woodley Park Accident was the lack of a rollback protection feature to stop the train when operated in the manual mode.

Operator Error

The Woodley Park Accident was the only case study in this research that was the of operator error. Research of this case study revealed that the main factor of this accident

was the alertness level of the train operator. The train operator’s alertness level was due to a lack of sleep, which was attributed to working an overtime shift on the morning of the accident.

Conclusion

The first case study took place on 6 January 1996, and involved the collision of WMATA Train T-111 with a standing train at the Shady Grove Metro Station, located in Gaithersburg, Maryland. The accident resulted in the Operator of Train T-111 being fatally wounded and the total property damages were between $2.1 and $2.6 million dollars.

The second case study took place on 3 November 2004, and involved the collision between two WMATA Trains at the Woodley Park Metro Station in Washington, DC. The accident resulted in 20 passengers being transported to local hospitals and estimated property damage of $3.5 million dollars.

The third case study took place on 22 June 2009, and involved the collision of two WMATA Trains near the Fort Totten Metro Station in Washington, DC. The accident resulted in nine people including the train operator were killed. Emergency response agencies reported transporting 52 people to local hospitals. Damage to train equipment was estimated to be $12 million dollars.

The research of these three case studies detailed accidents that involved operator error, mechanical error, and OCC oversight. These accidents revealed that if appropriate measures are implemented, United States mass transit rider security will improve. With enhanced operator training, improved system maintenance, and standardized operating procedures, the Metrorail Systems in the United States will operate more efficiently,

which will improve the public perception of mass transit, reduce lost operating costs, and enhance rider safety. As Metrorail Systems across the United States move forward and more passengers use Metrorail each year, safety is at the forefront of improvements being made to these systems.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Introduction

The focus of this chapter is to provide future recommendations for rider safety as it pertains to the Mass Transit Systems within the United States, with a focus on the WMATA Metrorail System. Both rider and system safety are important functions of Metrorail Systems. Safety features can help to increase or decrease rider numbers, as well as affect the revenue that is generated for mass transit systems. Current practices in place are the results of past NTSB recommendations, Federal Guidelines, and standard operating procedures that each Metrorail System may have in place. Providing further rider safety and increased Metrorail performance will not only help to alleviate rider concerns, but these improvements will assist in overall performance and operations to mass transit systems. Recommendations for increased rider safety and Metrorail performance will be presented as a method to enhance safety for riders.

Thesis Question

The primary question is: How can mass transit security in the United States (with a focus on the WMATA) be improved to protect its riders? The following are subordinate questions to this thesis: What is the history of the WMATA Metrorail System? What accidents have occurred in the past that has resulted in the loss of life or equipment? What recommendations and improvements can be made to improve rider security?

Recommendations

The first recommendations addressed is that of rider physical safety. Many rider's concerns are related to crime and safety issues that currently affect Metrorail Systems across the United States. Many citizens choose not to use mass transit due to either the actual or perceived issue of crime; whether it may be robbery, vandalism, or serious crimes such as murder or rape. These concerns ultimately result in both the loss of revenue and overall confidence of the Metrorail System. The increased presence of law enforcement officers, both uniformed and non-uniformed will help to address this issue. The addition of law enforcement officers at metro stop locations, on board trains, and mobile patrols will help to deter and reduce crime, while adding a sense of security to Metrorail riders. The addition of non uniformed officers on board trains can help to gather information as to what types of crimes are occurring and if needed, those officers can detain criminals on as needed basis. Another recommendation to address and improve rider safety is that of added security cameras. These cameras can be added on Metrorail trains and throughout metro stations throughout their service area. With current technology, these cameras can help to identify any criminal that has committed acts on metro property, which can assist in making arrests for committing crimes.

The second recommendations addressed is operator training and OCC procedures. As indicated by the analysis of the three case studies, the Shady Grove and Woodley Park Accidents were direct results of lack of operator training and OCC procedures. Many accidents are attributed to train operators not being properly trained, or lacking necessary training to respond to emergencies. With specific training requirements across the 14 Metrorail Systems in the United States, all train operators will operate on a national

standard for train safety, emergencies, and overall operations. With standard train operator policies implemented, all OCC policies and procedures across the United States would be the same. With federal funding, all operators and OCC personnel would attend national level training established by the NTSB. National level training would ensure that all train operators and OCC personnel across the nation would operate with the same requirements. This training would also help to restore confidence in riders across the United States, as mass transit systems would be up to date with federal training requirements, as they would be trained by an outside agency other than their respective transit system.

The third recommendation addressed is Metrorail system maintenance and upgrades. As indicated by the analysis of the three case studies, the Fort Totten Accident was a direct result of an equipment failure. By addressing these two concerns, all Metrorail systems will be safer and perform at a higher rate or performance. Conducting required system maintenance and upgrades will result in less train delays, equipment malfunctions, and lost revenue. The upgrades to improve performance may include rail upgrades, rail structure reinforcement, and power cable replacement. These improvements will result in less revenue being lost as opposed to performing maintenance and upgrades during operating hours. System maintenance and upgrades can be performed during non operating hours. Many Metrorail issues, such as a negative public perception, lost revenue, and decreased ridership can be improved by making necessary system upgrades. Public perceptions of Metrorail systems, specifically the WMATA system is that the system is not reliable and has safety issues. These perceptions are related to lost revenue as ridership decreases as riders are constantly left

guessing if their train will actually arrive and depart on time. By completing necessary maintenance and upgrading the system on a needed basis, the Metrorail systems will help gain the confidence of riders, as this will help to improve Metrorail performance and increase rider safety.

Recommendations for Future Research

There are several areas identified throughout this study that would benefit from additional research. This study was limited in its scope by focusing on the 14 Metrorail Systems in the United States, with a focus on the WMATA Metrorail System. It would be useful to examine Metrorail systems in other countries to examine if there is a problem with crime, rider safety issues, and overall Metrorail System performance and if so, what measures are in place to address these issue. Another area that this study would benefit from would be a visit with a General Manager and Supervisors of an area Metrorail System. This meeting would enable the researcher to interview system leadership to determine what current issues are currently at hand and what is being done to address those issues. A final topic of research would be to conduct surveys and interviews with all General Managers of the 14 Metrorail Systems in the United States to determine what issues are most prevalent within their system. Other areas to address with those General Managers would be; what issues do they deem most important to their respective system, what they are doing to address those issues, and what practices in the past have worked best for them.

Conclusion

Metrorail Systems are an important asset to large cities and the citizens that use them. As these systems continue to exist and rider figures increase, the threat of crime and system safety will always exist. Strategies to increase rider safety and system performance are always on the forefront of the minds of passengers as they utilize these systems on a regular basis. These strategies will continue to evolve over time to increase confidence and public perception of Metrorail Systems. Safety issues and system performance will never be 100 percent accurate, but with updated improvements and training the mass transit system will improve over time.

GLOSSARY

Automatic Train Control (ATC) Systems consists of three Subsystems. Automatic Train Protection: The ATP subsystem was designed to enforce safe operation of the system. It imposes speed limits to maintain train separation and allow for safe stopping distances between trains, ensures safe door operations, and provides control of interlockings. The first speed readout on the train operator's console indicates the ATP (or "limiting," or "design") speed. The system was designed never to allow trains to exceed the ATP speed in normal operation.

Automatic Train Supervision (ATS). The ATS subsystem was designed to monitor system status and provide the appropriate controls to maintain efficient train operation and scheduling. It is through the ATS subsystem that the OCC controller is able to set or change performance levels for trains across the Metrorail system.

Automatic Train Operation (ATO). The ATO subsystem performs basic train operating functions, including starting trains and accelerating to running speed, maintaining en route speed, and controlling train stopping and positioning at passenger stations.

Metrorail. Metro is the transit provider for the National Capital Region, providing safe, clean and reliable service to both residents and visitors. Our customers include more than a third of the federal government workforce and millions of tourists who visit the Nation's Capital every year. Metro operates the second largest heavy rail transit system, sixth largest bus network, and fifth largest paratransit service in the United States.

Metrorail carbodies. All are constructed primarily of aluminum extrusions that serve both as structural components and as exterior skin for the roof, side walls, and rear-end cowl.

Metrorail Operations Control Center. A location where teams of controllers monitor and direct operations throughout the Metrorail system. The Metrorail OCC, located in the Jackson Graham Building at 600 Fifth Street, N.W., Washington, DC, serves as the control center for the Metrorail system. The OCC is responsible for providing positive control over all station activities, train movements, and subsystems (power, automatic train control, automatic fare collection, and communications) necessary for the efficient movement of passengers.

Metro Operating Modes. The WMATA Metrorail system operates under an Automatic Train Control (ATC) system that was designed to allow for fully automated train operations requiring very little direct involvement by train operators. The degree of automation is partially determined through the use of the following modes:

Mode 1 (automatic): Normal train functions, including acceleration, speed, and braking, are controlled by the ATC system, with the operator responsible for monitoring console indicators and track conditions.

Mode 2 (manual with speed protection): Train acceleration and braking are manually controlled by the train operator, with over speed protection provided by the ATP subsystem.

Mode 3 (manual with automatic train protection cutout): All train operations are controlled by the operator, with no over speed protection. This operating mode is only used when malfunctioning equipment makes Mode 1 or 2 operation impossible.

Passenger. A person who is traveling in an automobile, bus, train, airplane, or other conveyance, especially one who is not the driver, pilot, or the like.

Telescoping. Occurs when a railcar body breaches the end structure of another carbody and passes into the structure of that carbody.

WMATA. Washington Metropolitan Area Transit Authority.

WMATA Service Area. Metrorail and Metrobus serve a population of 4 million within a 1,500 square-mile area. The transit zone consists of the District of Columbia, the suburban Maryland counties of Montgomery and Prince George's and the Northern Virginia counties of Arlington, Fairfax, and Loudon and the cities of Alexandria, Fairfax, and Falls Church. Overall, 45 percent of those working in the center core (Washington and parts of Arlington County) use mass transit.

BIBLIOGRAPHY

American Public Transportation System. “Public Transportation Benefits.” Accessed 17 November 2015. http://www.apta.com/mediacenter/ptbenefits/Pages/default.aspx.

Becker, Jo, and Lyndsey Layton. “Safety Warnings Often Ignored at Metro.” *The Washington Post*, 6 June 2005. Accessed 21 February 2016. http://www.washingtonpost.com/wp-dyn/content/article/2005/06/05/AR2005060500968.html.

Greater Cleveland Regional Transit Authority. “RTA Overview.” Accessed 20 May 2016. http://www.riderta.com/overview.

International Association of Public Transport. “Statistics Brief–World Metro Figures.” Accessed 15 February 2016. http://www.uitp.org/sites/default/files/cck-focus-papers-files/Metro%20report%20Stat%20brief-web_oct2014.pdf.

Layton, Lyndsey, and Steven Ginsberg, “20 Injured in Crash of 2 Red Line Trains,” *The Washington Post*, 4 November 2004. Accessed 10 April 2016. http://www.washingtonpost.com/wp-dyn/articles/A22466-2004Nov3.html.

National Transportation Safety Board. “Investigations.” Accessed 19 May 2016. http://www.ntsb.gov/investigations/process/Pages/default.aspx.

———. *NTSB Railroad Accident Report–2004 Woodley Park Accident*. Washington, DC: National Transportation Safety Board, November 2004. Accessed 11 April 2016. http://www.ntsb.gov/investigations/AccidentReports/Reports/RAR0601.pdf.

———. *Railroad Accident Report*. Washington, DC: National Transportation Safety Board, January 1996. Accessed 21 February 2016. http://www.ntsb.gov/investigations/AccidentReports/Reports/RAR9604.pdf.

———. *Railroad Accident Report*. Washington, DC: National Transportation Safety Board, 27 July 2010. Accessed 11 April 2016. http://www.ntsb.gov/investigations/AccidentReports/Reports/RAR1002.pdf.

Needle, Jerome A., and Renee M. Cobb, “Improving Transit Security.” Transit Cooperative Research Program. Accessed 14 May 2016. http://onlinepubs.trb.org/onlinepubs/tcrp/tsyn21.pdf.

The Metropolitan Transit Authority. “Network.” Accessed 20 May 2016. http://web.mta.info/mta/network.htm#statsnyct.

UITP Advanced Public Transport. “October 2014 Statistics Brief.” Accessed 15 February 2016. http://www.uitp.org/sites/default/files/cck-focus-papers-files/Metro%20report%20Stat%20brief-web_oct2014.pdf.

Washington Metropolitan Area Transit Authority. “Customer Accountability Report.” 31 March 2016. Accessed 27 April 2016. https://www.wmata.com/about_metro/general_manager/performance/CARe.pdf.

———. “FY 2015 Approved Budget.” Accessed 20 May 2016. https://www.wmata.com/about_metro/docs/FY2015%20Approved%20Budget%20Book.pdf.

———. “Metro Facts.” Accessed 11 May 2016. http://www.wmata.com/about_metro/docs/Metro%20Facts%202016.pdf.

———. “Metro System Map.” Accessed 17 November 2015. http://www.wmata.com/rail/docs/color_map_silverline.pdf.

———. “Metrorail.” Accessed 17 November 2015. http://www.wmata.com/rail/.

Wikipedia. “List of United States Rapid Transit Systems by Ridership.” Accessed 20 February 2016. https://en.wikipedia.org/wiki/List_of_United_States_rapid_transit_systems_by_ridership.